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Project 0 - Brainstorming Presentation

W-shaped Walker Vs. Inchworm Robot Design

Team Red

EECS 464: Hand-on Robotics
Fall 2025

Task Interpretation

Project Requirements Summary

- **Objective:** Race robot through 6m figure-8 track as faster as possible
- **Track Specification:** 50cm wide, inner radius 25cm, carpeted surface
- **Key Constraints:**
  Maximum 3 modules (2UB + 1 CR)
  No fully rotating parts allowed
  190° joint rotation limit
  Start within 60x40x150cm box
  Must avoid truck boundary disqualification

Team's Interpretation

- **Primary Goal:** Optimize for speed while maintaining steering precision
- **Critical Challenge:** Figure-8 navigation requires tight steering precision
- **Success Metric:** To complete lap without disqualification in <60 seconds

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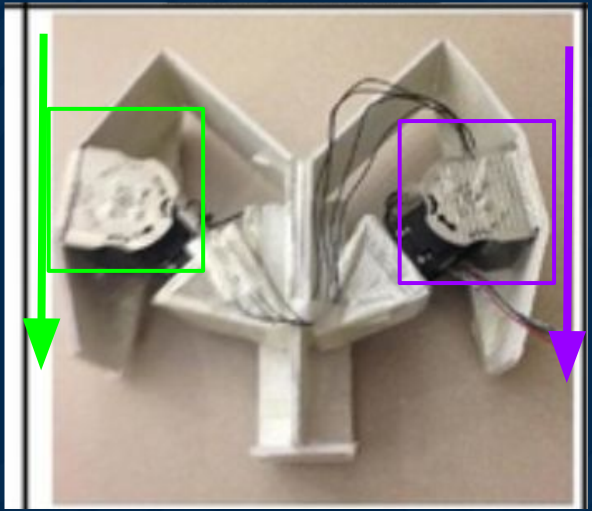
Design Option 1: W-shape Walker



Mechanism Overview (Based on 2016 Maize Team Success and 2013 Team Red)

Type: Two-motor asymmetrical friction walker with cardboard construction

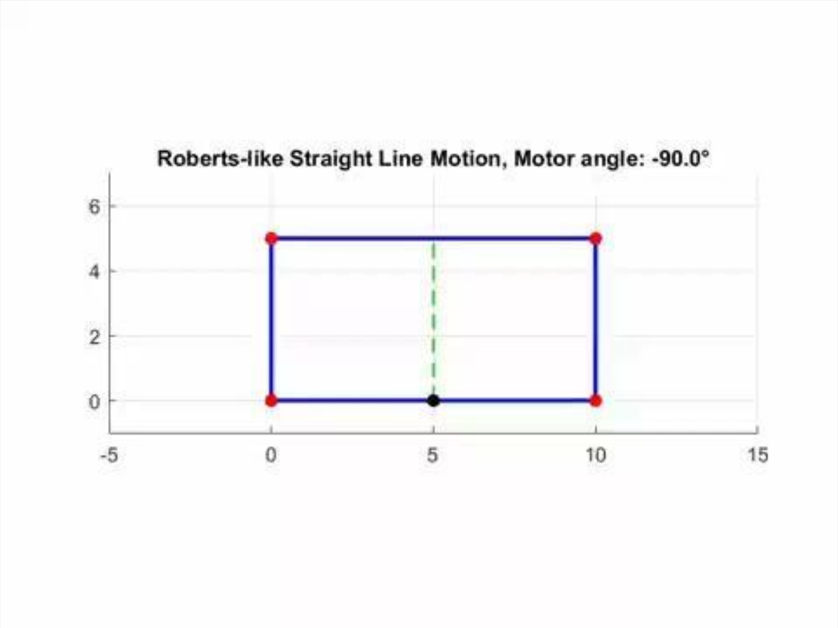
Module Configuration:

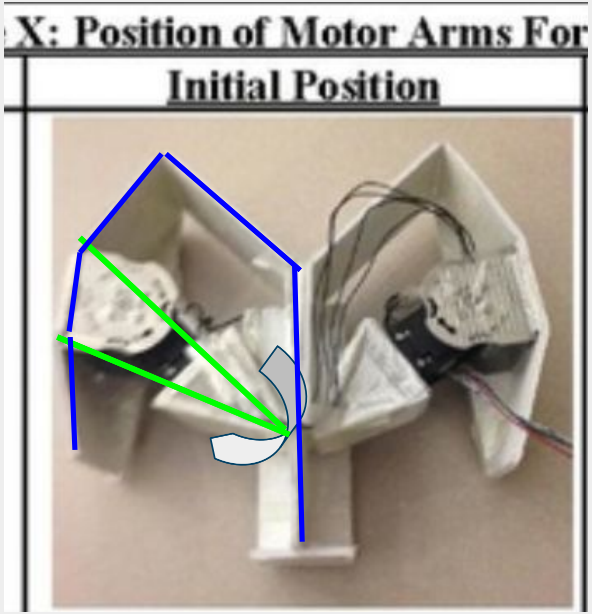
- **UB Module 1:** Controls left leg assembly (4-bar linkage)
- **UB Module 2:** Controls right leg assembly (4-bar linkage)
- **No CR Module:** Steering achieved through differential leg timing

Key Features from Proven Design

- **Asymmetric Friction Strategy:** High-grip ratchets create directional preference
- **Alternating Motion:** Left/right legs move in coordinated sequence
- **Steering Method:** Differential timing between legs creates curved motion
- **Speed Achievement:** Based on similar project from 2016 Maize team: 46.05s straight line, 3:33 full track completion

The W-shape-scuttle robot design employs a double Robert's linkage mechanism to create straight line motion.





Academic Source # 1 - Rochester Institute of Technology Linkage experiments.

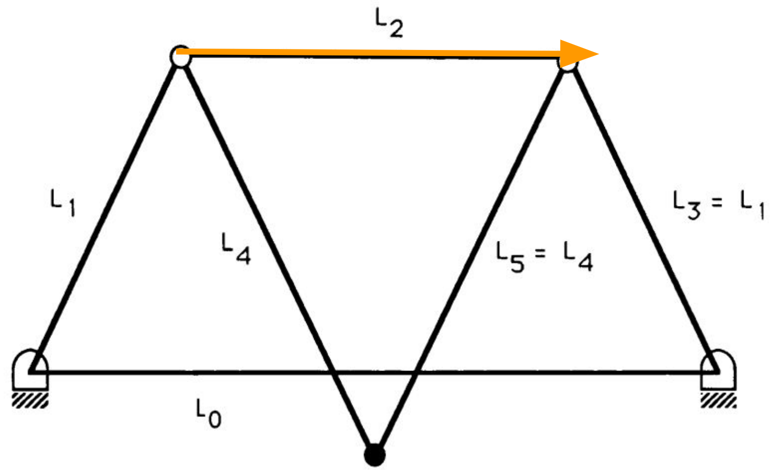


Figure 4.9 Roberts Linkage

p = 3.00, r = 2.00, s = 2.00, a = 1.00

b = 1.00

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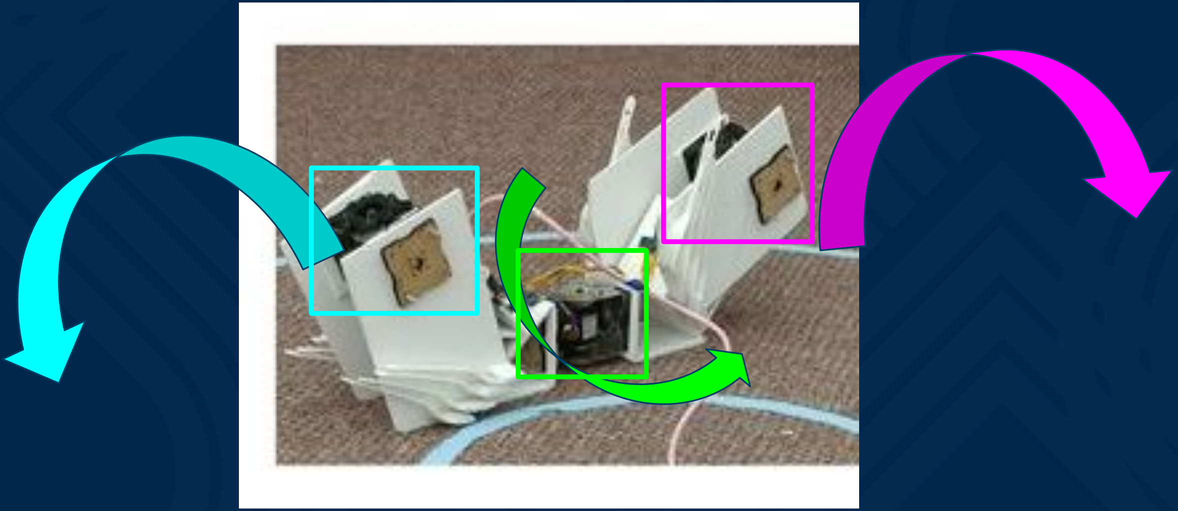
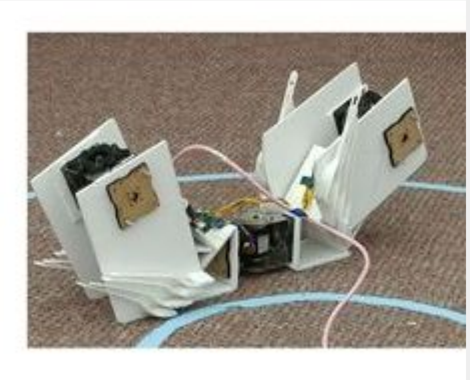
Option 2: Inchworm



Mechanism Overview

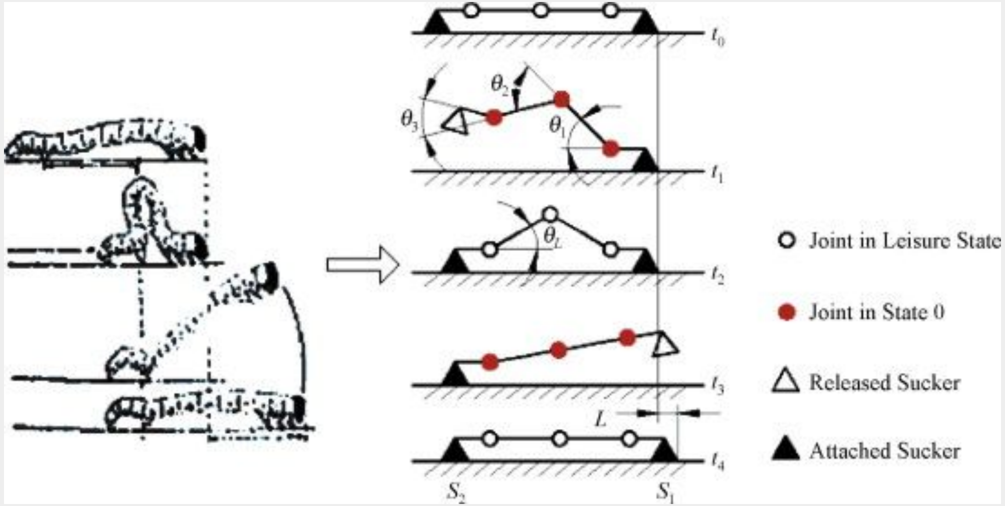
- **Module Configuration:**
  - **UB Module 1:** Controls main body extension/contraction
  - **UB Module 2:** Provides lateral steering during extension phase
  - **CR Module:** Body rotation for additional steering capability



Key Technical Features

- **Two-Phase Motion Cycle:**
  1. **Extension:** Body extends forward while rear maintains grip
  2. **Contraction:** Front grips, rear releases, body pulls forward
- **Steering Integration:** Lateral deflection during extension creates curved trajectories
- **Friction Management:** Active grip/release system rather than passive ratchets

The inchworm design has much less surface area to propel itself forward.



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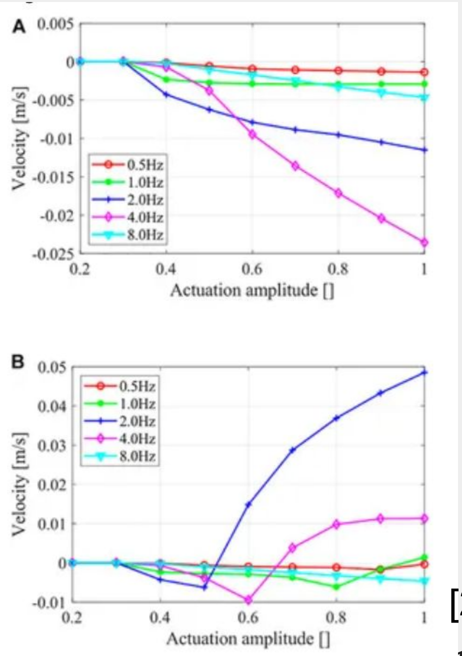
Academic Source #2 - Shanghai Robotics Institute

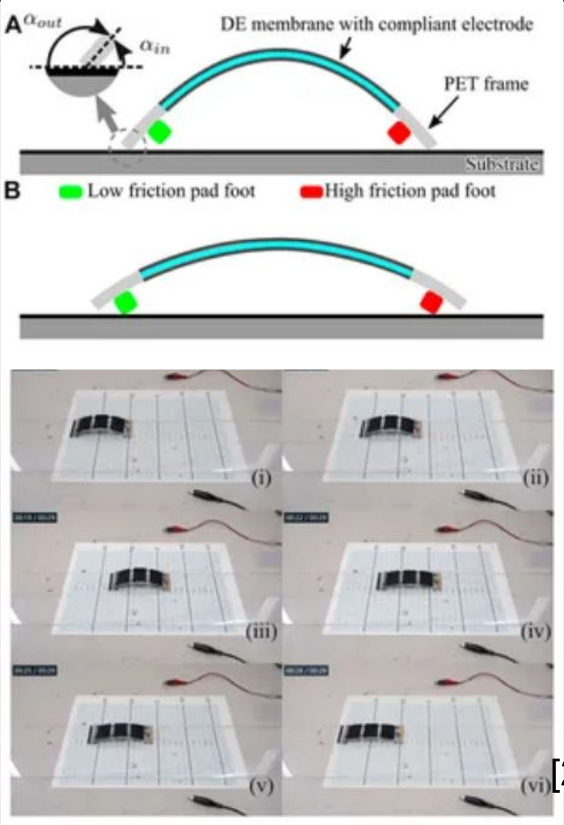
- The goal of the research was to create bidirectional movement with a minimalist inchworm design
- They used two different types of inchworm robots
  - Primitive Gait - One friction pad on each end
  - Compound Gait - One friction pad on each end as well as one in the middle
- The researchers created a mathematical model and simulations to predict how well different bend amounts and speed affect locomotion



[2]

Academic Source #2 - Shanghai Robotics Institute

- The researchers created a prototype that was able to switch direction when increasing voltage in the motors
- The article demonstrates the ability to use minimalist soft structure to create locomotion, which will help with keeping our motion forward facing



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Speed Data Sources and Assumptions (Quantitative Analysis)

W-shaped Walker Speed: 13 cm/s

Primary Source: 2016 Maize Team Final Report (similar project on W-shape Walker)

- **Measured performance:** 46.05 seconds for 6-meter straight line
- **Calculated speed:** 600cm ÷ 46.05s = 13.03 cm/s
- **Validation:** 2023 Red Team W-shape scuttler achieved similar performance range

Inchworm Speed: 15 cm/s

Primary Source: Green Team 2023 Final Report

- **Measured performance:** 38 seconds for 15-foot straight line
- **Calculated speed:** 457cm ÷ 38s = 12.03 cm/s actual
- **Adjusted estimate:** 15 cm/s potential (25% improvement with optimization)

Green Team achieved 12 cm/s through mechanical advantage
15 cm/s represents optimized version of their approach

Note: Green Team's inchworm variant achieved fastest straight-line speed but struggled with figure-8 navigation (110-143s vs Red Team's 67s)

Simple Performance Matrix Analysis

Performance Score Formula

Performance Score = (Speed × Reliability) / Build Complexity

(source: standard engineering matrix methodology)

Winner: W-shaped Walker (2.4× better performance score)

Assumptions:

- **Reliability percentages:** Based on historical team success rates
  - W-shaped: 85% (2 teams successful: 2016 Maize, 2023 Red)
  - Inchworm: 60% (1 teams successful: Green Team had reliability issues)
- **Build Complexity (1-10 scale):** Based on component count and integration difficulty
  - W-shaped: 4 (simple linkages, passive friction)
  - Inchworm: 8 (telescoping mechanism, active grip system)

Design	Speed (cm/s)	Reliability (%)	Build Complexity (1-10)	Performance Score
W-shaped Walker	13	85%	4	**2.76**
Inchworm	15	60%	8	1.13

Critical Failure Mode Analysis

Failure Mode	Probability	Impact	Mitigation Strategy
Friction Structure Breaks	Medium	Critical	Test the rigidity of the design. Find a solid attachment strategy.
Linkage Mechanism Binding	Medium	High	Proper joint clearances. Using the motor limits for a hard stop. Overlimiting the joints will make it lock up.
Motor Synchronization Loss	Medium	Medium	Software state machine, timing verification
Cardboard Structural Failure	Low	High	Tape reinforcement, stress testing
Boundary Violations (Track)	Medium	Critical	Conservative sizing, practice runs

We expect our points of failure to be mechanical issues.

- One directional friction.
  - Small structures are more likely to break, given the force of the robot against the ground.
- (In the case of the w-walker): Finding an intermediate design regarding the stroke length.
- The center of gravity positioned in the wrong location to not create enough friction.

Implementation Schedule

Development Timeline

	Milestone	Deliverable
1	Material Selection	Friction testing results
2	Prototype Build	Working linkage mechanism
3	Control Development	Basic motion programming
4	Integration Testing	Complete robot assembly
5	Optimization	Speed/steering tuning
6	P-Day Preparation	Final testing & practice

Scheduled Meetings

9/6:	11 am-5 pm
9/7:	3-10 pm
9/9:	6-8 pm
9/14:	3-10 pm
9/16:	6-8 pm
9/21:	3-10 pm
9/23:	6-8 pm

Resources

[1] A. Natesan, “Kinematic analysis and synthesis of four-bar mechanisms for Kinematic analysis and synthesis of four-bar mechanisms for straight line coupler curves straight line coupler curves.” Available: https://repository.rit.edu/cgi/viewcontent.cgi?article=5662&context=theses

[2] L. Du, S. Ma, K. Tokuda, Y. Tian, and L. Li, “Bidirectional Locomotion of Soft Inchworm Crawler Using Dynamic Gaits,” *Frontiers in Robotics and AI*, vol. 9, Jun. 2022, doi: https://doi.org/10.3389/frobt.2022.899850

[3] Zhang, Houxiang. (2009). Crawling gait realization of the mini-modular climbing caterpillar robot. Progress in Natural Science - PROG NAT SCI. 19. 1821-1829. 10.1016/j.pnsc.2009.07.009.

[4] OpenAI, “ChatGPT,” *ChatGPT*, 2025. Available: https://chatgpt.com/c/68b791c1-5188-832c-bf24-6a10728100ba. [Accessed: Sep. 03, 2025]